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June 9, 1995

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By Messenger

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, N.W.
Washington, DC 20554

Re: CC Docket No. 92-297, RM-7872, RM 7722
Ex Parte Presentation

Dear Mr. Caton:

Enclosed for filing with the Commission in this docket are five copies of a report prepared by the MITRE Corporation entitled "Critique of the Bellcore Report."

This report, prepared by MITRE under contract with the Satellite Broadcasting and Communications Association ("SBCA"), is submitted on behalf of the Global Satellite Communications Coalition. It summarizes a comprehensive analysis conducted by MITRE of the April, 1995 Bellcore Report entitled, "Interference Analysis for Co-Sharing of the 28GHZ Band by the Local Multipoint Distribution Service (LMDS) and the Fixed Satellite Service (FCC)."

The MITRE report explains a number of serious technical flaws and unrealistic assumptions in the Bellcore Report. MITRE disagrees with Bellcore's assumptions about the feasibility of co-frequency LMDS/FSS sharing and reaches the following conclusion:

> "Based on our review of the Bellcore Report and other relevant material available, we can find no realistic method of band-sharing between LMDS and FSS services."

Copies of this letter and the MITRE report are being provided simultaneously to the individuals identified below.

Respectfully submitted,

SATELLITE BROADCASTING AND
COMMUNICATIONS ASSOCIATION

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Senior Vice President

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Critique of the Bellcore Report

Interference Analysis for Co-Frequency Sharing of the 28 GHz Band by the Local Multipoint Distribution Service (LMDS) and the Fixed Satellite Service (FSS)

MTR 95W0000065
June 1995

Dr. Reuben E. Eaves
W. Morris Holmes, Jr.
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EXECUTIVE SUMMARY

This report presents the results of a study conducted by The MITRE Corporation under contract to the Satellite Broadcasting and Communications Association. The report examines the work performed by Bellcore in their April 1995 report entitled *Interference Analyses for Co-Sharing of the 28 GHz Band by the Local Multipoint Distribution Service (LMDS) and the Fixed Satellite Service (FSS).*

The Bellcore report concludes that "the Local Multipoint Distribution Service (LMDS) and Fixed Satellite Service (FSS) can share the 27.5- to 29.5-GHz frequency band with 99.9 percent availability for both services." Bellcore bases this conclusion on LMDS system parameters different from those presented to the Federal Communications Commission (FCC) Negotiated Rulemaking Committee (NRMC) by LMDS system proponents. Bellcore also advocates the use of antennas having improved performance for the FSS earth terminals, and proposes an FSS/LMDS spectrum protocol to increase compatibility.

After examining the Bellcore study, MITRE finds that the Bellcore analysis fails to demonstrate the compatibility of LMDS and FSS in a common frequency band and does not support the Bellcore conclusion.

A fundamental sharing problem arises because both LMDS and FSS services are intended for the same customer base. In densely populated urban areas, FSS terminals and LMDS receivers will be located in neighboring buildings—sometimes even in the same household—meaning that the acceptable separation between FSS terminal and LMDS receiver must be measured in meters, not kilometers. Under these conditions, the LMDS system improvements recommended by Bellcore (higher LMDS hub transmitter power, lower acceptable C/(N+I) and improved LMDS antenna sidelobe performance) will be of little help in mitigating the effects of interference.

The Bellcore report considers only one set of LMDS interference scenarios, involving the CellularVision LMDS system. In addition, the report re-characterizes the Texas Instruments system in such a way as to indicate a reduced susceptibility to interference. The report also claims incorrectly that the criteria used in this analysis are sufficient to cover all other LMDS systems. However, the acceptability of system changes and performance criteria to Texas Instruments is not known. In addition, other architectures must be expected for LMDS systems not yet defined.

We find that the Bellcore analysis of LMDS availability, even with the modified LMDS system parameters, fails to demonstrate the compatibility of LMDS and FSS in a common frequency band. Several key factors lead to our conclusion:

The objective C/(N+I) of 13 dB for a system -wide availability of 99.9 percent is not achieved in the presence of the 15 uniformly distributed Teledesic T1 terminals in a Teledesic cell assumed by Bellcore even when the modified LMDS system parameters are employed

The assumption that FSS terminals will be uniformly distributed throughout the FSS beam area is not realistic

LMDS availability in the presence of clustered Teledesic terminals (either T1 or 16 kbps) is not 99.9 percent (0.1 percent unavailability) but drops to the range of 99.0 percent to 94 percent (1 percent to 6 percent unavailability) and interference worse than Bellcore estimates by a factor between 10 and 60

LMDS availability in the presence of clustered T1 terminals from one Spaceway system is not 99.9 percent but can reasonably be expected to be on the order of 98 percent or less (more than 2 percent unavailability) and a factor of 20 worse than estimated by Bellcore

The availability of the subscriber-to-hub link is not addressed by Bellcore but, as the NRMC concluded and we show, represents a serious interference problem

FSS networks in addition to Teledesic or Spaceway were not considered but would further degrade LMDS availability

Beyond finding that Bellcore's analysis fails to support a conclusion that 99.9 percent availability can be achieved by LMDS in the presence of interference from FSS uplink transmissions, we take issue with some of the fundamental assumptions used by Bellcore. The following paragraphs detail some of these differences.

Bellcore computes a system-wide availability defined as "LMDS availability is the fraction of space and time where LMDS is totally unencumbered." The problem with this approach to computing availability is that it averages the degree of interference in areas of locally clustered active FSS transmitters with the degree of interference in sparse activity areas. In other words, Bellcore computes the average with uniform weighting, when it should apply heavier weighting to clustered areas—it is inaccurate to accord areas of little usage the same importance as areas with significant usage.

A more meaningful definition of LMDS system-wide availability would be the fraction of time that LMDS is totally unencumbered, averaged over all subscribers. Using this definition, the significance of interference-prone areas generally associated with a high density of LMDS and FSS users is not diluted by uniform averaging with remote, low-use areas.

We also contend that the 99.9 percent system availability criterion that the Bellcore report defines as acceptable to LMDS system operators is a misleading measure, since it ignores service denial to individual LMDS users. Furthermore, selecting 99.9 percent as a value for system-wide availability is a misuse of a historically accepted short-term-outage criterion. LMDS system operators may well be willing to accept a system outage rate of less than 0.1 percent, but individual users who suddenly experience interference to reception of their television programs cannot be expected to be so accommodating. Coordination with LMDS users is impractical for FSS systems, which require wide market penetration for economic viability. It is probable that consumer political power and the right of LMDS users to retain service will effectively bar FSS system entry to urban and suburban areas containing LMDS systems.

The Bellcore report contains other technical flaws. It ignores interference between cells, and mis-models the number of LMDS cells in a Teledesic cell. It assumes that LMDS availability can be based on a C/(N+I) in the range 8 to 13 dB, but the resulting picture quality will neither satisfy the stated LMDS picture quality objective nor meet customer expectations for high-quality video service. In addition, some LMDS subscribers will experience marginal or unsatisfactory reception for long periods of time. We also note that the picture quality estimated by Bellcore as a function of received carrier-to-noise plus interference is at serious variance with CellularVision test results provided to the NRMC.

The variation in the quality of an LMDS signal resulting from Bellcore's use of the C/(N+I) to define the level of interference-free service will not be acceptable to an LMDS subscriber because it will result in a noticeable difference in signal quality between different video LMDS channels or a constant variation in the signal quality of one LMDS channel.

The interference analysis conducted by Bellcore only considers CellularVision's analog system and a modified version of the Texas Instruments system considered by the NRMC. These two system architectures, however, are not necessarily representative of all LMDS system architectures or of the LMDS system architecture that may be employed commercially in the 27.5 – 29.5 GHz band, especially considering that the CellularVision system is analog and LMDS systems are likely to be deployed commercially using digital technology.

The assumption that LMDS subscriber antennas can be produced and maintained in a home or office environment with significantly better sidelobe performance than recommended by the ITU-R is unrealistic. Interference at levels higher than predicted will affect the availability of LMDS to its subscribers.

Bellcore also suggests that FSS antenna sidelobe performance far better than that considered by the NRMC is possible. They determine LMDS availability for several assumed levels of sidelobe improvement, but ignore practical economic experience reflected in ITU Recommendations and recommend the use of much lower sidelobes, based on Andrew catalog antennas.

One of these antennas, the Andrew SHX Parabolic, never has existed. The Andrew SHX Antenna is no longer in production. Its hog-horn design was an excellent approach for fixed point-to-point applications atop telephone buildings and radio relay towers where production cost, size, and weight are not major considerations. Our review of performance achieved by actual production antennas similar to those that could be considered for small antenna applications confirms that going beyond ITU Recommendations for sidelobe performance in consumer-installed terminals (which are operated for many years on consumer premises with little or no maintenance) is unrealistic.

Bellcore's third major proposal for accommodating sharing between the LMDS and the FSS is an FSS-LMDS spectrum protocol that would establish a list of preferred frequencies in each LMDS cell to be selected for use by FSS terminals on a priority basis. The concept contains several serious flaws. One flaw is the failure to consider the spectrum required for both the subscriber-to-hub link and the FSS. We note, for example, that CellularVision proposes to use the 2-MHz guard bands between video channels for subscriber-to-hub transmissions while the Bellcore spectrum protocol requires that FSS transmissions use these same guard bands as first-priority choices of frequencies. This protocol would prevent CellularVision from achieving satisfactory availability on their subscriber-to-hub links.

It should be noted that the Bellcore report considered only the Teledesic and Spaceway systems, and considered them only separately—the report did not consider additional FSS systems (such as the Loral network and others). The addition of other systems to the environment almost certainly renders the Bellcore protocol unworkable.

The protocol is also incompatible with satellite technology and system designs. Both traditional transponder technology and newer on-board processing require contiguous bandwidth for users. This is incompatible with the Bellcore protocol, which selectively places users in scattered gaps.

Other concerns about the Bellcore protocol include:

The protocol largely ignores the details and significant problems in the technical implementation and operation of the protocol

The protocol ignores the institutional issues and problems associated with implementing the protocol

The protocol will significantly limit efficient use of the spectrum by the FSS

No provision is made for applying the protocol to multiple FSS systems sharing the same band

If the *FSS/LMDS Spectrum Protocol* is not needed, as stated in the Bellcore report, it should not be used to add to the control burden of FSS systems. In any event, it will not solve interference problems in cells that contain both LMDS terminals and FSS terminals at densities approaching the planned systems' capacities.

Bellcore claims that, in practice, LMDS availability will be better than their calculations indicate because of conservative assumptions used to model interference. In fact, however, Bellcore availability calculations cannot possibly be viewed as underestimating LMDS availability. The assumptions that the objective C/(N+I) can be dropped to the range of 8 to 13 dB, and that subscriber antennas can be maintained with significantly better sidelobe performance than recommended by the ITU-R, are, in our opinion, wildly optimistic. Other factors that Bellcore claims will result in availability 60 to 90 percent better than calculated are also invalid; the Bellcore approach, far from being conservative, is quite radical and optimistic in nature.

Based on our review of the Bellcore report and other relevant material available, we can find no realistic method of band-sharing between LMDS and FSS services. The Bellcore approach cannot serve as the basis for establishing co-equal allocations for the FSS and LMDS in a common frequency band.

SECTION 1

INTRODUCTION

The MITRE Corporation conducted this study of the April, 1995 Bellcore report, *Interference Analyses for Co-Sharing of the 28 GHz Band by the Local Multipoint Distribution Service (LMDS) and the Fixed Satellite Service (FSS)* under contract to the Satellite Broadcasting and Communications Association. The Bellcore report concludes that the Local Multipoint Distribution Service and Fixed Satellite Service can share the 27.5– to 29.5-GHz frequency band with 99.9 percent availability for both services. Based on the results of this study and for the reasons presented herein, MITRE disagrees with this conclusion.

Bellcore reaches its conclusion based on three system considerations which it claims would allow co-frequency sharing of the 28-GHz band:

> LMDS system improvements including increased hub transmitter power, lower operating C/(N+I) at the LMDS subscriber receiver, and an improved LMDS antenna mask
>
> Achievement of 99.9 percent system availability, based on assumptions regarding the number, location, and distribution of LMDS and FSS stations
>
> Use of a spectrum protocol that would assign FSS uplink frequencies in designated or unused portions of the band to avoid interference

Section 2 provides an overview of the Bellcore report and the MITRE examination of it; subsequent sections of this report discuss the three factors outlined in the preceding paragraph. Section 3 discusses the issues of LMDS System Availability in the presence of FSS uplink interference and the effect of the system improvements proposed by Bellcore on system availability. Section 4 discusses the system engineering considerations of both the LMDS and FSS antenna patterns on the interference signals. Section 5 critiques the feasibility of the Bellcore Protocol approach.

SECTION 2

OVERVIEW

> "Since LMDS systems are anticipated to be deployed before FSS systems, the satellite community is uncomfortable with the concept of first-come first-served. If a plan could be developed to guarantee that the FSS systems could operate in the same geographical areas as LMDS systems without degrading LMDS system availability below acceptable levels, then this concern could likely be alleviated."
> —Paragraph 1.1, Bellcore report

The definition of "acceptable level" of LMDS availability is the primary problem in the Bellcore report. Our study of this issue indicates that the Bellcore definition of "acceptable level" is not valid. LMDS system operators may find an average 99.9 percent system wide availability ($\leq$ 0.1 percent revenue loss) acceptable. However, individual LMDS system users who invest in LMDS hardware to receive entertainment TV and other services who are accustomed to receiving these services with high individual user availability, will not. A decline in individual user availability due to a recent FSS terminal installation would be wholly unacceptable, even though the system wide availability may be 99.9 percent

In such a case, it is reasonable to expect LMDS users to complain loudly and effectively to their congressional representation and the Federal Communications Commission (FCC). Political pressure, plus the first-come, first-served frequency-regulation practice, will make urban and suburban areas with LMDS service off-limits to FSS services such as those considered in the NRMC report.

The figure of 99.9 percent availability (0.1 percent unavailability) is a reasonable criterion only for short-term outages (the sum of rain plus short-term interference outages). FSS interference into LMDS terminals is not, however, restricted to the short term—FSS will support telecommuting and other new interactive digital video applications. These services will operate over the business day, extended over at least the US time zones as well as by flex-time working arrangements. LMDS users affected by FSS interference will experience very long periods of unavailability. Accordingly, even if the Bellcore analysis were correct and 99.9 percent system-wide availability were achieved, many individual LMDS users would not experience acceptable levels of LMDS availability.

Even if the range of C/(N+I) specified in the Bellcore report is used to define the range of LMDS picture quality considered to be acceptable, the variation in signal quality experienced by LMDS subscribers will not be acceptable to subscribers using this standard. Any noticeable variation in signal quality between different video channels or the constant variation in the signal quality of one channel will not be acceptable to an LMDS subscriber. When LMDS systems are deployed initially, because of the high C/(N+I) value and the absence of FSS transmitters, LMDS systems will provide a very high quality video signal to the subscribers. To the extent that the deployment of FSS transmitters will reduce the quality of the signal received by the LMDS subscribers consistent with the range of C/(N+I) defined in the Bellcore report, it will be unacceptable to LMDS subscribers. For example, an active Teledesic Standard Terminal ("TST") within an LMDS cell transmits with a duty cycle of 1/9. The C/(N+I) at an LMDS subscriber receiver during the period that the active TST is not transmitting is greater than 31 dB and during the period that the active TST is transmitting may fall to 13 dB. Since the C/(N+I) remains above 8 dB, this would be an acceptable level of interference under the Bellcore analysis. However, it is clear that the subscriber will experience periodic noticeable and extremely annoying variation in the received video signal quality corresponding to the duty cycle of an active TST. The maximum acceptable variation in the C/(N+I) should be considered in measuring acceptable interference to LMDS subscribers.

The Bellcore report also assumes that coordination must take place with LMDS system operators, not with the individual LMDS users denied service. This is incorrect.

> "Shared use of a frequency band traditionally involves coordination with existing users when a new terminal is installed. New terminals must demonstrate that they will not cause harmful interference into existing stations."
> —Bellcore report Paragraph 1.1

Coordination with thousands of existing LMDS users is clearly impractical for FSS systems that require wide market penetration for economic viability.

Notwithstanding these other concerns, the Bellcore report does not demonstrate that the figure of 99.9 percent LMDS system availability can be achieved, since the simulation assumptions used in the report are flawed. One critical flawed assumption is the location of FSS and LMDS terminals; the Bellcore report assumes that "each (FSS) uplink is assumed to be randomly located within the borders of the LMDS cell." LMDS availability is calculated using "the joint space-time distribution of the percent of LMDS cell area that is degraded," which is equivalent to assuming that LMDS terminals are also randomly distributed. The term random in this context implies a uniform density distribution, but the distribution of either terminal set is not uniform. Many factors, including terrain, transportation facilities, and commercial development, lead to clustering; clustering, in turn, increases the probability of interference, in some cases dramatically.

The Bellcore report also ignores the fact that LMDS and FSS terminals are further correlated as individual pairs, over and above the correlation caused by population and enterprise clustering. Once an LMDS system has achieved successful economic penetration in an area, many of the dwellings that are candidates for FSS terminals will have LMDS terminals. This reduces the acceptable terminal separation requirement to meters (not kilometers, as assumed in the Bellcore report); accordingly, FSS telecommuters must deny entertainment TV to their family (and neighbors) while working.

The FSS-terminal-to-LMDS-terminal interference simulations contained in the Bellcore report do not consider interference between cells, only interference within cells. There are also questions about the number of LMDS cells assumed to fall into one Teledesic FSS cell, and reducing the FM pre-detection C/N+I value acceptable to LMDS to 8 dB (from 26 dB) is optimistic at best.

The Bellcore report considers only one set of LMDS interference scenarios, involving the Cellular Vision LMDS system. In addition, the report re-characterizes the Texas Instruments system in such a way as to indicate a reduced susceptibility to interference. The report also claims incorrectly that the criteria used in this analysis are sufficient to cover all other LMDS systems. However, the acceptability of system changes and performance criteria to Texas Instrument are not know. In addition, other architectures must be expected for LMDS systems not yet defined.

On the FSS side, the Bellcore report considers only the Teledesic and Spaceway FSS systems. Additionally, it considers these two systems only individually, not as individual interference contributors whose interference effects must be summed. Successful FSS establishment will lead to other FSS system operators—indeed, the entire purpose of the ACTS technology program was to open the 28-GHz band to FSS systems, relieving the pressure on lower, more crowded spectrum and improving communications efficiency. FSS systems may be placed at two-degree intervals over the equatorial arc, which will allow for decades of growth.

The Bellcore report ignores FSS-to-LMDS hub interference. Since LMDS will be there first, FSS operators will be responsible for solving any problems with two-way operations. FSS-to-LMDS hub interference will take the form of interference from FSS terminals to the LMDS hub main beam.

The Bellcore report describes a number of mitigation techniques in an attempt to redesign the LMDS and FSS systems to achieve compatibility, rather than simply analyzing the systems designed by the different vendors. It may be possible to design LMDS systems that avoid either interference to, or interference from, nearby FSS systems; however, the LMDS systems described in the NRMC documents, even after Bellcore modifications, do not avoid severe interference from FSS terminals into neighborhood LMDS terminals.

The Bellcore report suggests two interference mitigation techniques for FSS terminals, greatly reduced sidelobe radiation and the FSS/LMDS Spectrum Protocol. These techniques, however, cannot overcome the deficiencies described earlier, and even if they would solve the interference problem, these changes are economically impractical. Some of the suggested changes are technically impossible. The Andrew SHX Parabolic (-68.0 dB) antenna referred to in the Bellcore report is not—and never has been—available. The Andrew SHX is no longer in production since it could compete economically only in a small niche market. While this hog-horn antenna had excellent performance, it was bulky, heavy, and expensive.

The Bellcore report also takes ITU pattern recommendations lightly, especially considering that a system design must meet economic as well as technical performance criteria. System designers must also be aware that sidelobe specifications for newly delivered antennas are not representative of system performance achieved by consumer-installed antennas that must operate for many years from rooftops, a demanding environment that discourages maintenance while exposing systems to the vagaries of weather, animals, and trees. ITU pattern recommendation include these factors for professionally installed and maintained terminals, but the ITU recommendations cannot be considered conservative for either LMDS or FSS consumer installed and maintained terminals.

> "The Teledesic Gigalink Terminal (TGT) uses a bandwidth of 800 MHz, making it impossible to develop a suitable spectrum protocol. Since there will be relatively few Gigalink Terminals, the locations of these terminals can be determined via traditional methods of frequency coordination to insure that harmful interference is not caused into existing LMDS receivers."
> —Bellcore report, Section 4.1

One "traditional method" of preventing interference to pre-existing terminals is to deny a license to a TGT in an urban or suburban area. This solution is, of course, not compatible with co-equal frequency sharing. The *FSS/LMDS Spectrum Protocol* documents another traditional method to minimize interference from FSS terminals with LMDS terminals: try to find a frequency not in use. This protocol requires the development and periodic maintenance of a data base containing an ordered list of frequencies or frequency blocks for every LMDS cell; this data base is to be coordinated with each individual LMDS operator. This is in addition to coordinating FSS intra-system and inter-system frequency usage.

If the *FSS/LMDS Spectrum Protocol* is not needed, as stated in the Bellcore report, it should not be used to add to the control burden of FSS systems. If it is needed, it will not solve interference problems in cells that contain both LMDS terminals and (multiple system) FSS terminals at densities approaching planned system capacities.

One statement, presented in the Bellcore report in bold type, seems to be either totally meaningless and trivial or logically indefensible:

> **From the satellite viewpoint, the full allocated bandwidth is available everywhere for uplink transmissions (even if all transmissions are in the same LMDS cell), and there is no capacity penalty for implementing this spectrum protocol as uplinks are NEVER prohibited from transmitting on any given frequency.**

This statement raises a number of questions. Since the protocol is voluntary, does it actually prohibit anything? If the full allocated bandwidth is available everywhere, why cannot the TGT be accommodated? Does the statement that uplinks are never prohibited from transmitting on any given frequency imply that it is acceptable to ignore LMDS terminals denied operation? If so, from whose point of view?

Based on our review of the Bellcore report and other relevant material available, we can find no realistic method of band-sharing between LMDS and FSS services.

SECTION 3

LOCAL MULTIPOINT DISTRIBUTION SERVICE (LMDS) SYSTEM AVAILABILITY

3.1 SUMMARY

We conclude that the Bellcore analysis of Local Multipoint Distribution Service (LMDS) availability, even with the modified LMDS system parameters, fails to demonstrate the compatibility of LMDS and FSS in a common frequency band. Several key factors led to our conclusion:

The objective C/(N+I) of 13 dB for a system-wide availability of 99.9 percent is not achieved in the presence of the 15 uniformly distributed Teledesic T1 terminals in a Teledesic cell assumed by Bellcore, even when the modified LMDS system parameters are employed

The Bellcore report's assumption that FSS terminals will be uniformly distributed throughout the FSS beam area is unrealistic

LMDS availability in the presence of clustered Teledesic terminals (either T1 or 16 kbps) is not 99.9 percent but drops to the range of 99 percent to 94 percent; interference is worse than Bellcore estimates by a factor of between 10 and 60

LMDS availability in the presence of clustered Spaceway T1 terminals is not 99.9 percent but can reasonably be expected to be on the order of 98 percent or less, a factor of 20 worse than estimated by Bellcore

FSS Networks in addition to Teledesic or Spaceway were not considered but would further degrade LMDS availability

Bellcore does not address the availability of the subscriber-to-hub link, which, as the NRMC concluded, and we show, represents a serious interference problem

Further, the Bellcore report's assumption that the LMDS availability can be based on a C/(N+I) of 13 dB is unlikely to satisfy customer expectations. With this value, some LMDS subscribers will experience marginal or unsatisfactory reception for long periods of time.

The Bellcore report's assumption that subscriber antennas can be produced and maintained in a home or office environment with significantly better sidelobe performance than recommended by the ITU-R is unrealistic. Availability of LMDS to its subscribers will be affected when interference is greater than predicted because the antennas will not perform as assumed by Bellcore.

Other factors that Bellcore claims will result in availability 60 to 90 percent better than presented in their report are invalid for the reasons discussed in the succeeding paragraphs.

The Bellcore approach, far from being as conservative as claimed, is quite radical in nature. It is not suitable for use as the basis for establishing co-equal allocations for the FSS and LMDS in a common frequency band.

3.2 BELLCORE APPROACH TO DETERMINATION OF AVAILABILITY

The objective of the Availability Computation section of the Bellcore study is to determine the overall availability of reception in an LMDS cell of signals that exceed a minimum carrier-to-noise-plus-interference ratio in the presence of interference from FSS transmitters.

The first step in Bellcore's development of the overall availability percentage is the calculation of a degradation distribution function for a single LMDS cell for various numbers of FSS transmitters in the LMDS cell. A Monte Carlo simulation assigns random locations to the FSS transmitters within the LMDS cell. This method then determines the statistical distribution of the percent of LMDS cell area that experiences harmful interference as a function of the percent of time degraded. The method then calculates distributions for both clear sky and rain conditions, and merges them, based on rain being present for 1 percent of the time. In each case, the method calculates distributions for one interferer in an LMDS cell, two interferers, and so on, up to a maximum number of interferers, determined by the capacity of the FSS network. The method assumes that a binomial distribution determines the probability of having "n" transmitters located within an LMDS cell; it then combines the degradation distributions to determine the percent of area of a typical LMDS cell that will experience interference as a function of the percent of time degraded. Finally, the method averages this combined degradation distribution to determine the availability of a randomly located LMDS receiver.

This procedure is applied in cases where the interferer population consists of 15 Teledesic T1 transmitters distributed over a Teledesic cell, and presents curves of LMDS system-wide performance. The procedure also presents results for cases where the T1 transmitters are clustered within a few LMDS cells rather than being located randomly. When the interferer population consists of 1,440 16-kbps Teledesic standard terminal users, the approach used by Bellcore deviates from that described: Bellcore does not use the binomial distribution to determine the probability associated with any given number of interferers within a cell. Rather, it assumes that the transmitters are uniformly distributed over the LMDS cells within a Teledesic cell and performs multiple Monte Carlo simulations of random locations of transmitters and receivers within an LMDS cell. Bellcore then averages the results of these simulations to develop the LMDS availability figure.

Bellcore does not calculate LMDS availability in the presence of Spaceway interferers since it contends that the availability will be higher than the Teledesic case (since it assumes that the average density of Spaceway transmitters is lower than that of Teledesic transmitters). Also, the frequency band requested by Spaceway only partially overlaps the 27.5- to 29.5-GHz band, and Bellcore recommends that Spaceway transmit in the non-overlapping portion of the band to the maximum extent possible.

3.3. Bellcore Assumptions

The following paragraphs detail the specific assumptions employed in the Bellcore study, and include our assessment of the validity of each assumption.

Bellcore assumes that the amount of degradation within an LMDS cell is a function of time, due to the changing locations of the active FSS uplinks as FSS subscribers throughout the FSS cell initiate and terminate access to the FSS network. We believe that this assumption is incomplete. It should also be noted that, since the FSS subscribers have fixed locations, it is possible to experience various levels of interference within the cell as a function of distance and angle from these FSS subscribers.

The Bellcore report assumes that the degradation distribution is calculated based on each FSS uplink being randomly distributed within the borders of an LMDS cell. We believe that this assumption is not justified. In practice, FSS terminals are not likely to be randomly distributed throughout an LMDS cell, since population is not uniformly distributed. In addition, FSS locations may well be directly correlated with the location of LMDS subscribers.

Bellcore assumes that the ITU antenna mask is applied to the transmitting Teledesic Standard Terminal sidelobes. We believe that this is a valid assumption (it forms the basis for the NRMC calculations).

The Bellcore report assumed that a revised antenna mask is applied to the receiving CellularVision subscriber terminal sidelobes. We believe that this assumption is invalid, since the ability to consistently achieve and maintain the assumed sidelobe levels in consumer product antennas is questionable.

Two 120-W traveling-wave-tube amplifiers replace the CellularVision 100-W hub transmitter , according to the assumption in the Bellcore report. We believe that this assumption is questionable, since this change will result in additional implementation costs of a type that CellularVision deemed unacceptable for operation at 41 GHz.

Bellcore assumed that the Texas Instruments LMDS would not use power control, thereby raising the transmitter power by 12 dB over what would be necessary in clear sky conditions. This change is plausible but not recommended, since it poses the potential for interference into FSS satellite receivers.

Bellcore assumed that the minimum acceptable LMDS signal carrier-to-noise-plus interference ratio for unencumbered reception is 13 dB. This is a subjective assessment, but for many LMDS subscribers (particularly video subscribers), 13 dB will not result in anything close to the studio quality CellularVision claims as its objective because a C/(N+I) of 26 dB is required to produce a signal having fine to excellent quality.

The Bellcore report assumes a degradation distribution for clear skies for 99 percent of the time, and a degradation distribution for heavy rain conditions for 1 percent of the time. The report uses this two-step rain condition rather than averaging the effects over all rain rate distributions. We believe that this is a valid assumption.

A Teledesic cell consists of 64 (8 by 8) 5-km-radius (center to corner) LMDS cells, according to the Bellcore report. We believe that this assumption is misleading. For CellularVision, the cell radius is 4.8 km, center to edge, allowing approximately 39 LMDS cells per Teledesic cell. The TI system has a radius of 5 km, and the VideoPhone system cell size is .8 km. The much larger number of LMDS cells assumed by Bellcore artificially increases the availability percentage, because on average, fewer cells will have FSS transmitters located within their boundaries and, an LMDS subscriber is closer to a hub if there are more hubs (cells) per Teledesic cell.

The Bellcore report assumes that 15 active T1 rate Teledesic Standard Terminal (TST) uplinks are continuously in use, that the locations of the uplinks are randomly distributed over the Teledesic cell, and that they are uniformly distributed over time. The implication here, although not well stressed in the report, is that the average T1 usage in each LMDS cell considered is the same (uniform) in every cell. This assumption oversimplifies the distribution of T1 uplinks, and does not allow for the analysis of non-uniformly distributed areas (such as urban and suburban areas).

The binomial probability distribution is used in the Bellcore report to describe the probability of having "n" active FSS uplinks in a given cell at a given time. This distribution is valid only for the case of uniform average usage throughout the geographic area considered. A more general distribution, such as the multinomial distribution, would have yielded more accurate results (refer to Section 3.4).

Bellcore uses the binomial distribution to weight and combine the degradation distributions computed for zero to fifteen simultaneously active T1 rate interferers, yielding the overall degradation distribution. Again, this assumption is valid only for uniform average activity throughout the cells considered, a situation rarely if ever encountered in actual practice.

The Bellcore report integrates the overall degradation distribution over the percentage time degraded to yield the unavailability; 100 percent minus this number is called the availability.

Bellcore computes the system wide availability as the weighted average of the availability in the LMDS cells where FSS uplinks are clustered, and the availability (100 percent) in the other remaining cells. Note that the term weighted here means weighted by the relative number of clustered cells to remaining (unclustered) cells. We believe that this is the most significant fallacy in the computation of system-wide availability. The individual availabilities from each LMDS cell, weighted by the average ratio of T1 links active within that cell to the total number of T1 links available, is the correct method of calculating availability. It is inaccurate and misleading to give the same importance to areas of little use as is accorded areas with significant use. Section 3.4 describes the consequences of using a more realistic measure of availability.

No interference effects from an FSS uplink to LMDS receivers across cell boundaries take place in the Bellcore report's assumptions. This assumption is not valid, as this effect can be important, particularly when the LMDS receiver is in the main beam of an FSS interferer in an adjacent cell.

The Bellcore report assumes that Teledesic's system causes the worst LMDS availability, and that this covers the Spaceway case. This assumption is not valid, since Bellcore has grossly underestimated the density of Spaceway terminals in LMDS cells (refer to Section 3.5). LMDS availability in the presence of the Spaceway network will be significantly lower than assumed by Bellcore.

3.4 AVAILABILITY BASED ON PERCENTAGE OF LMDS SUBSCRIBERS AFFECTED

In the Bellcore report, the analysis of FSS interference into LMDS receivers is based on a concept called LMDS availability: "LMDS availability is the fraction of space and time where LMDS is totally unencumbered." Using this as a figure of merit, the report presents the results of LMDS availability computations. Typical results are in the range of 99.5 percent availability or better.

The problem is that this approach averages the degree of interference in areas of locally clustered active FSS transmitters with the degree of interference in areas of only sparse activity. This approach computes the average with uniform weighting, when clustered areas should receive heavier weighting. The rationale for this is that the number of LMDS users and FSS users in a given vicinity are related to population density and therefore highly correlated. In addition, it can be argued there is a high likelihood of users requesting the use of both services.

To be more meaningful, the definition of LMDS System availability should be rephrased as the fraction of time that LMDS is totally unencumbered, averaged over all subscribers.

Note that with this definition, the significance of interference-prone areas generally associated with a high density of LMDS and FSS users is not diluted by uniformly averaging over remote, low-usage areas. The binomial distribution may represent the distribution of the number of active FSS up-links in a group of LMDS cells; however, LMDS availability can vary significantly within a cell as a function of position, or more precisely, as a function of separation distance and angle from an FSS up-link. Therefore, certain LMDS subscribers experience consistently less availability than other subscribers within that cell.

In the Bellcore report, figure 3-1 represents a plot of degradation distribution (the percentage of cell area degraded as a function of the percentage of time that quantity of area is degraded). This is plotted for various numbers of active T1 TSTs, with a two-level weighting function applied to combine the effects of clear sky and heavy rain conditions. Bellcore uses the binomial distribution to weight and combine the degradation distributions, resulting in a family of curves for various clustering densities.

The underlying assumption in the binomial distribution is that the long-term averages of the number of active FSS transmitters in each LMDS cell are equal (that is, uniform). In addition, all 15 active T1-rate FSS up-links must be assumed to be active within those LMDS cells, and there are no active T1 rate links in the remainder of the LMDS cells within the Teledesic cell. Therefore, precautions are required to ensure that there is a uniform distribution over a multi-LMDS cell area. The area under consideration should be sufficiently small such that uniformity is achieved.

If the analysis violates the uniformity assumption, then the binomial distribution is inappropriate, and the situation calls for a different distribution function. Whatever the case may be, whether uniform or non-uniform, the appropriate weighting function used to compute average system-wide availability over all LMDS cells must be defined as the mean fraction of total number of active up-links (15 T1 rate up-links) attributed to each cell.

In the case of the binomial distribution, where usage is uniform over x cells, and N T1 rate links are available, the mean number of active up-links in each cell is N/x. The mean fraction of total active up-links is $(N/x)/N = 1/x$. This is the recommended weighting function that should be employed when computing system-wide availability for the x cells in the cluster. Note that the weighting function is zero for all remaining cells.

The curves of Bellcore figure 3-4 represent the unavailability, or 100 percent minus the availability. Assuming a binomial FSS distribution, the upper curves correctly represent system-wide availability. The display of system-wide unavailability presented (the bottom curve) is incorrect—LMDS cells not included in the binomially distributed cells must have zero weighting. It is here where the unimportant, unsubscribed, low-unavailability areas inaccurately dilute high levels of unavailability (top curves) occurring in the clustered cells.